Lowered Doppler Current Profiler Post-Cruise QC Report
2015 P16N CLIVAR Repeat Section

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1 Introduction

This report describes the results from the post-cruise quality control of the LADCP data collected during the two legs of the 2015 P16N GO-SHIP (CLIVAR repeat hydrography) cruise on the NOAA Ship *Ronald H. Brown*. Using two ADCPs installed on the hydrographic rosette, one looking downward (DL) and the other upward (UL), full-depth profiles of all three components of the oceanic velocity field were collected at most stations. Entirely different methods are used for processing LADCP/CTD data for horizontal and vertical velocity, requiring separate QC (Sections 3 and 4, respectively).

2 Instrumentation and Data Acquisition

Due to a travel incident, the engineer in charge of LADCP data acquisition during leg 1 was unable to participate on the cruise. Data collection was carried out by several volunteers (see leg-1 cruise report) and, with exception of the first week when there were technical problems with data transmission, the data were transmitted to shore at least once per day for processing and monitoring by Thurnherr. During leg 2, Darren McKee from LDEO collected the LADCP data and carried out shipboard processing and QC, as described in the leg-2 cruise report.

Leg	Profs.	Grp.	DL/UL	u,v QC	w QC	Notes
1	1–40	1	WH150/300	(pass)	(pass)	DL bad transducer; #9 DL/UL truncated
	41–79	2	WH150/300	pass	pass	#41 missing; #49 shallow
	80–95	3	WH150/300	fail	fail	DL bad beam
	96–112	4	WH300/600	fail	fail	insufficient range
2	113–117	5	WH150/300	pass	pass	
	118–133	6	WH300/300	(pass)	pass	marginal range
	134–171	7a	WH150/300	pass	pass	
	172–207	7b	WH150/300	pass	pass	#89 shallow profile

Table 1: Instrument combinations and QC notes; DL and UL indicate down- and upward-looking instruments, respectively. See text for potential problems with profile groups marked as "(pass)".

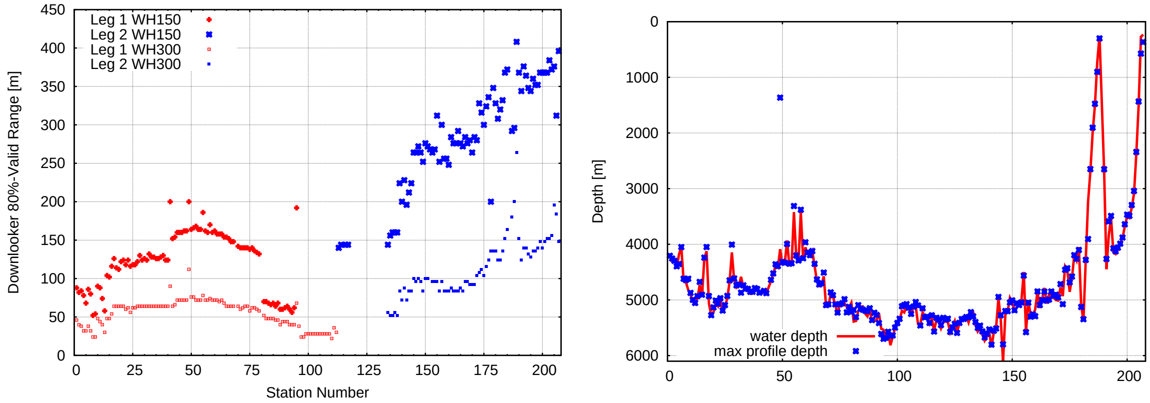

Figure 1: Left panel: Instrument range. Right panel: LADCP-profile bottom depth.

The LADCP profiles of leg 1 were collected with four different instrument combinations (Table 1). As soon as data transmission to shore was set up, it became clear that the downward-looking 150 kHz ADCP (DL) was not working correctly and that the range of the upward-looking 300 kHz ADCP (UL) alone was insufficient for horizontal-velocity processing, which requires gap-less ADCP profiles and minimum ranges of ≈65 m or better (Figure 1, left panel). Therefore, the DL was replaced with a spare 150 kHz instrument on station 41. For unknown reasons, no good LADCP data were recoded on station 41, and the LADCP data on station 49 were not collected during the deep CTD cast to ≈4000 m but, rather, during a shallower, secondary cast to 1200 m (Figure 1, right panel). While the replacement DL developed a bad beam after station 79 it was left on the rosette because the only remaining spare instrument was a 600 kHz WH600 ADCP, which is not expected to yield good data in this region of weak acoustic backscatter. By station 95 it had become apparent that the data collected with the DL with the bad beam were not of sufficient quality for horizontal-velocity processing and a WH300/WH600 combination was used for the remainder of this cruise leg.

The LADCP profiles on leg 2 were also collected four with different instrument combinations (Table 1). A first group of profiles (113–117) was collected with a DL cobbled together from the two WH150 used on leg 1 (transducer from profile group 1, electronics from profile group 2) and dubbed “Frankenhead.” For comparison, a set of profiles (118–133) was collected next with a dual WH300 combination, using a spare 300 kHz ADCP shipped to Honolulu for the 2nd cruise leg. As the WH150/WH300 combination yielded better data (see below), on station 134 the configuration was returned to the one used on stations 113–117. On station 172 the UL was swapped with the spare WH300 to determine whether there are significant differences between the two WH300 instruments. (None were observed.)

LADCP data quality is sensitively dependent on instrument range (Figure 1, left panel), which depends on the acoustic scattering environment. During the first cruise leg acoustic backscatter was comparatively weak, resulting in reduced range of valid measurements compared to the second leg. Beginning with profile ≈130, acoustic backscatter increased more-or-less monotonically northward along the cruise track.

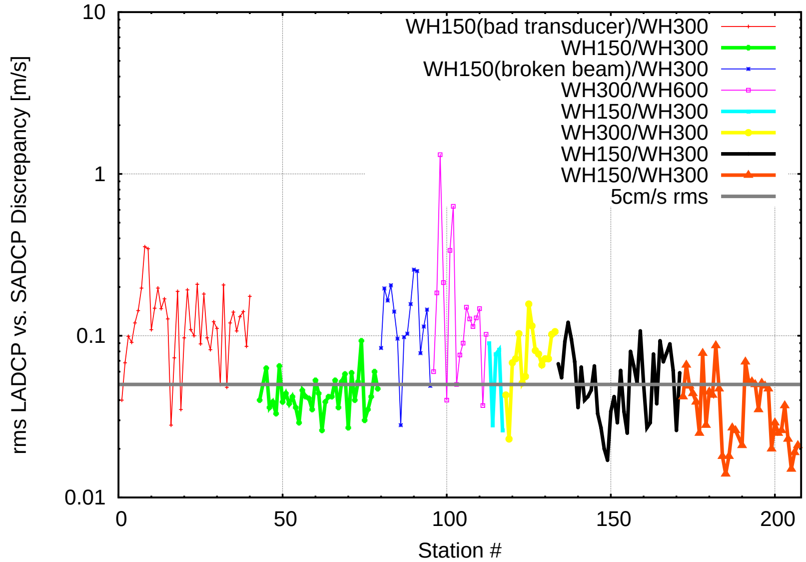

Figure 2: *rms* LADCP-SADCP horizontal velocity differences vs. profile numbers; low values indicate good agreement. Each station group (Table 1) is plotted with a different color.

3 Horizontal Velocity

The overall quality of the horizontal LADCP velocities is assessed by processing all profiles with the velocity-inversion method (LDEO_IX_12 software), using the bottom-track (BT) and ship-drift (GPS) constraints and comparing the resulting LADCP velocities near the sea surface to the corresponding SADCP velocities (Figure 2). [Except for profile #41, which does not have valid LADCP data, and #189, which is too shallow for processing with the LDEO_IX software (≈45 m bottom depth) the data from all P16N profiles are processable.] Based on data from other cruises, high-quality LADCP and SADCP data typically agree within 3–6 $\mathrm{cm \cdot s^{-1}}$ when averaged over a few profiles — in case of the P16N data processed with velocities from all ADCP bins (as is customarily done), only the profiles from groups 2, 5, 7a and 7b fulfill this criterion.

However, during preliminary processing of the leg-2 data it was noticed that the DL (WH150) velocities in the bins far from the transducer are biased, causing large inversion residuals in many of the profiles, and that discarding the velocities from bins >9 further improves many of the LADCP-derived horizontal-velocity profiles (see leg-2 cruise report for details). In order to investigate this observation, all profiles were processed multiple times using different bin ranges. The results, shown in the left panel of Figure 3, are quite unexpected in that the LADCP errors of all profiles collected with WH150 instruments *increase* when the data beyond bin 6 are used for processing. Profile groups 1 and 7 (collected with the same WH150 transducer) behave similarly in that the errors increase more-or-less monotonically with increasing cutoff bin number, whereas the errors of group 2 remain approximately flat, i.e. it does not seem to matter whether the profiles are processed with bins ≤6 or with data from all bins. Based on these observations, data from all WH150 bins >6 were discarded before final processing. The right panel in Figure 3 shows profile-group averaged LADCP errors for three different DL cutoff bin numbers. As expected, the profiles collected with WH300 DL instruments do not improve significantly when the data from the far bins are discarded. Based on

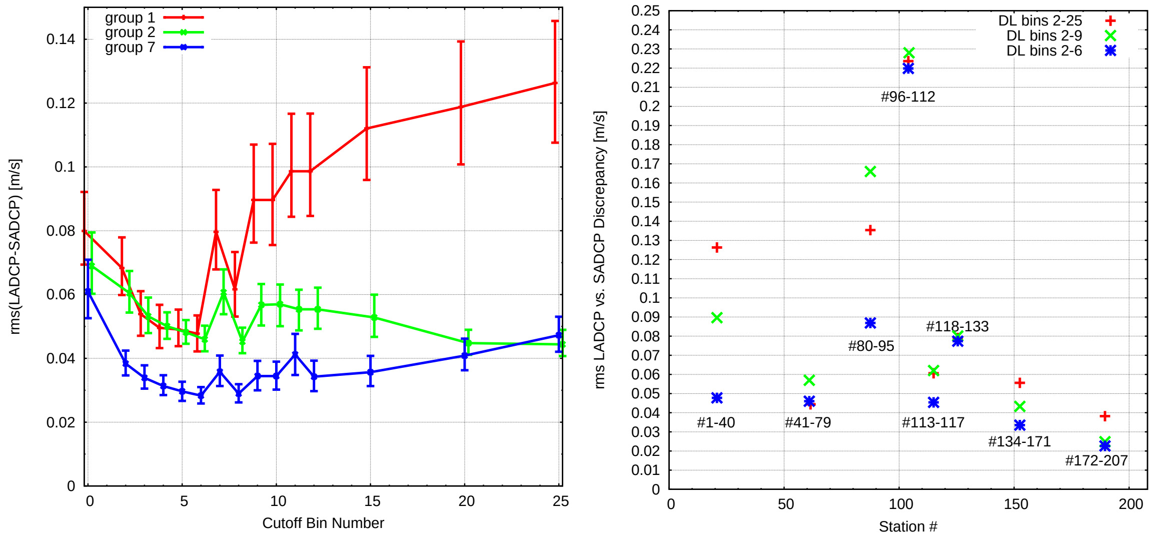

Figure 3: Left panel: *rms* LADCP-SADCP horizontal velocity differences vs. cutoff bin number for the large profile groups collected with WH150 DL instruments (Table 1); low values indicate good agreement. Right panel: profile-group averaged *rms* LADCP-SADCP horizontal velocity differences for 3 different cutoff bins.

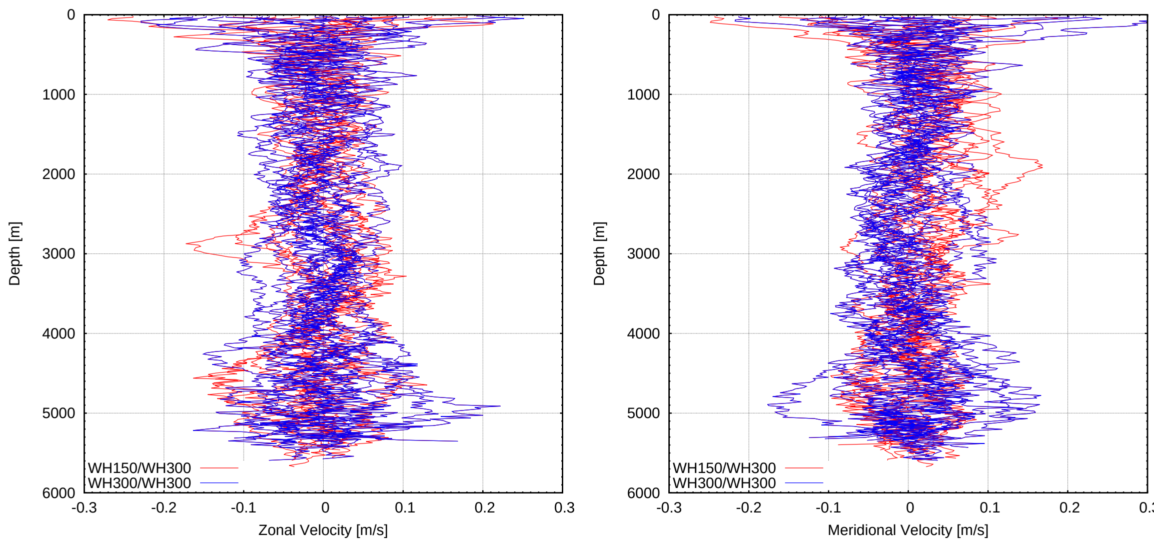

Figure 4: Leg-2 velocity profiles 113–140 collected with different instruments and processed with all available referencing constraints. Left: zonal velocities. Right: Meridional velocities.

these results, the horizontal-velocity profiles in groups 1, 2, 5, 7a and 7b are of good quality, whereas the horizontal-velocity profiles of groups 3, 4 and 6 are bad and should not be used (Table 1).

While the LADCP vs. SADCP velocity differences of the profiles collected with two WH300 ADCPs (group 6; #118–133) at $8\,\mathrm{cm\cdot s^{-1}}$ are higher than they should be, it is important to note

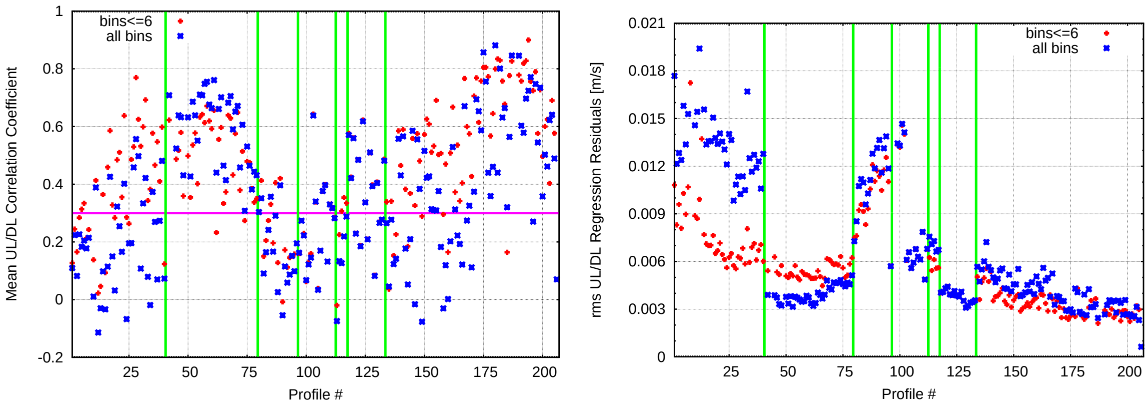

Figure 5: Vertical-velocity DL/UL correlations. Left panel: Correlation coefficient vs. profile number for two different cutoff bins; high values indicate good agreement. Green vertical lines separate the profile groups listed in Table 1. Magenta line shows approximate minimum correlation from visually acceptable profiles. Right Panel: Corresponding regression residuals scaled by $1/\sqrt{2}$; low values indicate good agreement.

that for final processing all available referencing constraints are used, including the SADCP velocities near the sea surface, i.e. the final velocity uncertainties are smaller than the ones shown in the figures in this document. Comparison of the WH300/300 profiles with nearby WH150/300 profiles reveals no clear signs of anomalies in either velocity component (Figure 4). As, furthermore, the vertical velocities of these profiles are of high quality (Section 4 below), this group of profiles is included in the post-cruise processed data set of horizontal velocity, which comprises profiles #1-8, #10-40, #42–79, #113–188 and #190–207 (groups 1, 2, 5–7).

4 Vertical Velocity

The `LADCP_w` software, version 1.2 was used to process the LADCP data for vertical ocean velocity. In contrast to horizontal velocity, the two w measurements at a given depth (from the DL and UL instruments) are completely independent. Diagnostics based on linear regressions of UL vs. DL-derived w are therefore useful measures of profiles quality. Figure 5 shows two such statistics: correlation coefficients in the left panel and regression residuals (scaled by $1/\sqrt{2}$) in the right panel. The scaled regression residuals can be taken as a quantitative estimate of the accuracy of the individual w_{ocean} samples in a profile. Based on the profiles processed with all bins (blue symbols) only profile groups 2, 6 and 7b are unambiguously of acceptable quality ($R \geq 0.3$ and residuals $\leq 0.006\,\mathrm{m \cdot s^{-1}}$). Discarding all data from WH150 bins >6 significantly improves the correlation statistics of the additional profile groups 1, 5 and 7a (red symbols) to overall acceptable levels. Inspection of the individual vertical-velocity profiles indicates poor agreement between DL and UL data in profiles #1–13. The final w_{ocean} data set comprises profiles #14–40, #42–79, as well as #113–207 (most of group 1, groups 2, 5–7).

Importantly, the regression statistics of profile group 2 are significantly better when all data are used than when the data from the far bins are discarded (Figure 5) — this is what one would expect from a good ADCP. Additional processing runs confirm that both instruments in group 2 were well behaved, as the correlation between DL and UL data increases monotonically with cutoff bin number

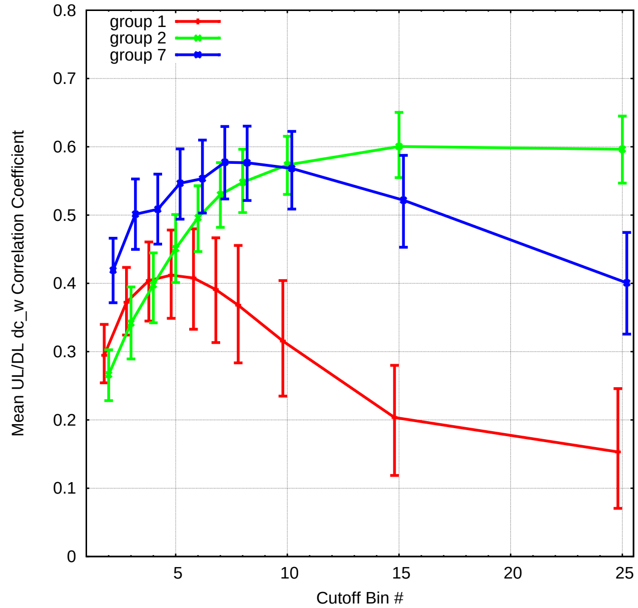

Figure 6: Vertical-velocity DL/UL correlation coefficient vs. cutoff bin number for the large profile groups collected with WH150 DL instruments (Table 1); high values indicate good agreement.

(Figure 6). The profile groups collected with the other WH150 transducer, however, should clearly all be processed without data from the far bins. For final processing, data from all bins are used for groups 2 and 6, whereas the DL data from bins >6 are discarded before processing the profiles from groups 1, 5 and 7. [Additional processing runs were carried out in an attempt to find alternative criteria based on error velocity or correlation, rather than bin number, but those attempts were not successful.]

In an attempt to visually confirm that the different instrument combinations returned comparable vertical velocities, a meridional section of internal-wave VKE density is shown in Figure 7. The two primary spatial patterns are i) higher VKE in the upper ocean than in the abyss and ii) a break in VKE levels near the critical latitude for semidiurnal PSI with higher/lower VKE at lower/higher latitudes, respectively. (The pattern is quite weak and will have to be confirmed with additional observations.) Importantly, there are no apparent breaks in the spatial patterns coinciding with instrument changes (solid black lines).

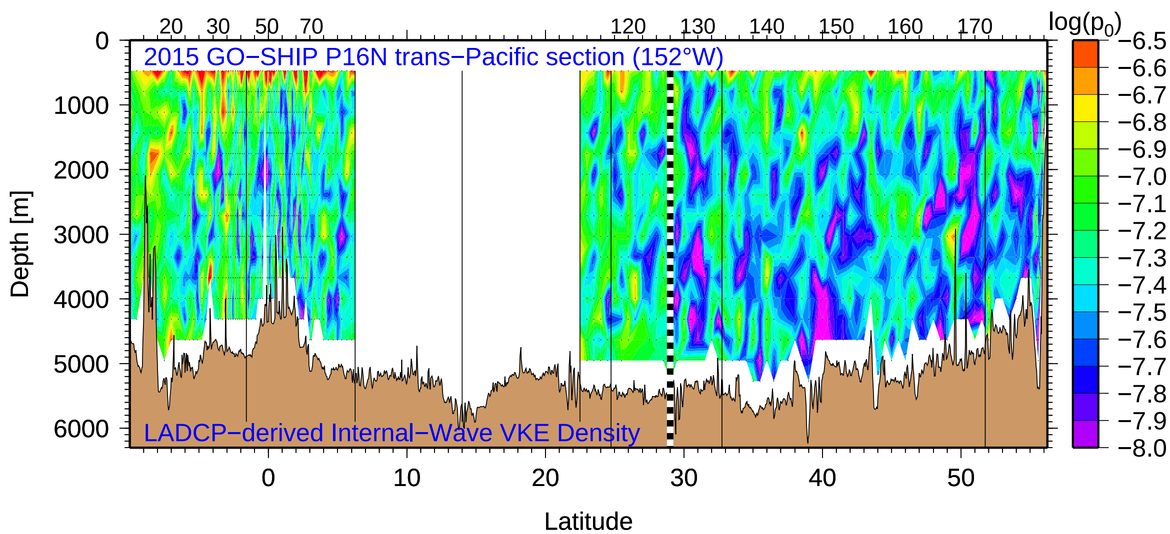

Figure 7: LADCP-derived finescale Vertical Kinetic Energy (VKE) density, in units of $m^2/s^2/(rad/m)$, which is dominated by high-frequency (near-N) internal waves. Thin vertical lines indicate changes in LADCP instrumentation (Table 1). The black-and-white vertical line at 29°N indicates the critical latitude for Parametric Subharmonic Instability (PSI) interactions involving the semidiurnal tide. Poleward of the PSI critical latitude VKE levels are lower than at latitudes below 29°, with corresponding *rms* vertical velocities of $0.6\,\mathrm{cm{\cdot}s^{-1}}$ and $0.9\,\mathrm{cm{\cdot}s^{-1}}$, respectively.